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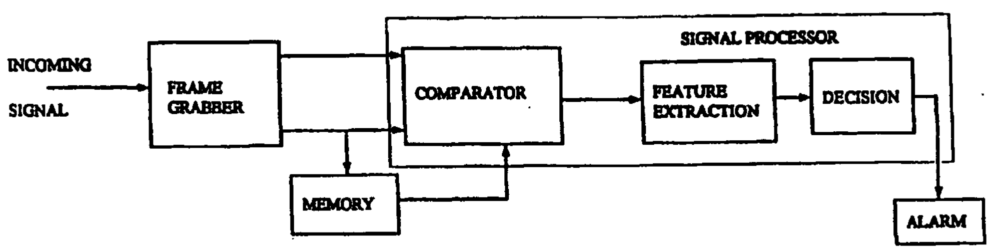
(54) Title: SMOKE DETECTION



(57) Abstract

A smoke detection system comprising video camera monitoring means, video frame comparison means, signal processing means, and alarm generating means dependant on an output from the signal processing means; the signal processing means being arranged to analyse successive frames acquired by the video camera monitoring means and to compare the intensity and/or colour of individual pixels or group of pixels so as to consider the overall characteristics and inter-relationships of these pixels so as to detect the presence of smoke characterised in that the signal processing means analyses a plurality of different types of change in the said characteristics and inter-relationships.

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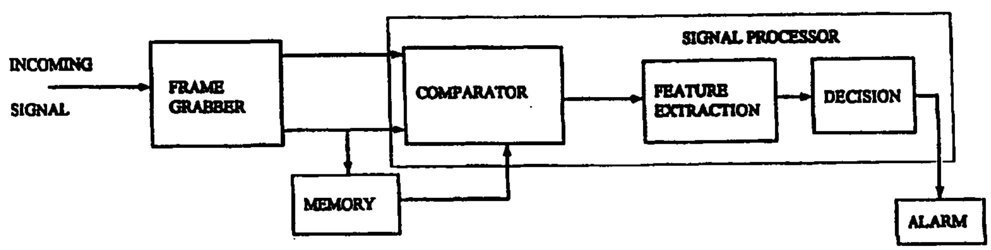

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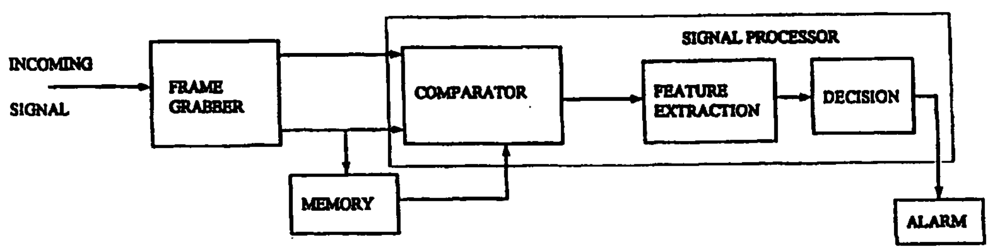

(57) Abstract

A smoke detection system comprising video camera monitoring means, video frame comparison means, signal processing means, and alarm generating means dependant on an output from the signal processing means; the signal processing means being arranged to analyse successive frames acquired by the video camera monitoring means and to compare the intensity and/or colour of individual pixels or group of pixels so as to consider the overall characteristics and inter-relationships of these pixels so as to detect the presence of smoke characterised in that the signal processing means analyses a plurality of different types of change in the said characteristics and inter-relationships.

by the video camera monitoring means and to compare the intensity and/or colour of individual pixels or group of pixels so as to consider the overall characteristics and inter-relationships of these pixels so as to detect the presence of smoke characterised in that the signal processing means analyses a plurality of different types of change in the said characteristics and inter-relationships.

Generally the signal processing means will provide one frame (often, but not necessarily always, the immediately preceding frame) as a reference and compare the current frame with that reference.The signal processing means will compare, within a selected region of that frame, the manner in which pixels or groups of pixels have changed.

There are a series of different kinds of change which can be analysed and the following is a list of some of these:

- an overall gate as a starting point to determine whether significant change has taken place

- value of pixels identified as converging towards a mean value. In effect this means that extremes of contrast are falling and the image is becoming more grey.

- edge information changes. Edge information can be obtained by comparing two frames of which one has been shrunk by a few pixels relative to the other.

The edge information can be used in two ways to define an emerging smoke condition, the one being to ascertain when edge detail is being lost, and the other being to distinguish between a softly defined image such as a smoke cloud and a harder image such as a moving person.

- dynamic parts of the overall image are identified as becoming static, or conversely static parts of the image become more dynamic.

- compactness. This looks at the size and placement of measured differences in pixel content. If the changed pixels are distributed in small isolated groups this will be indicative of an emerging smoke condition.

- opacity. Opacity is calculated by comparing the value (brightness or intensity) of the changed pixels to those in the reference image. It looks for a difference to indicate a reduction in visibility and hence the emergence of smoke.

- shape. Characteristics of shape which are known to be representative of an emerging smoke or fire condition.

Generally at least three, preferably the first, second and third changes referred to above, should be analysed although other combinations of the types of changes can be employed.

In practice a rule based analysis will be used initially based on three or four of the different kinds of change, and if this indicates a potential smoke condition then statistical analysis will be carried out, for example by means of a Bayesian Analysis. The statistical analysis will generally be based on all measured changes while the rule based analysis may trigger a smoke condition based on only a few of the measured kinds of difference.

The rule based analysis may be operated by weighting each selected individual analysis and summing the result, for example using a point count system (the individual values of which are ascertained empirically) to provide a pass/fail form of scoring.

Generally a selected zone of the overall image will be analysed, and this may be selected to exclude non-typical

regions of the screen area such as where personnel movement or other expected variation is likely to occur. Alternatively the whole area of the screen image may be analysed.

An embodiment of the invention will now be described by way of example with reference to the accompanying diagrammatic drawings in which:-

Figure 1 is a schematic arrangement of an apparatus according to the invention.

Referring to Figure 1, an incoming signal enters a frame grabber from the output of one or more closed circuit video cameras and the output of the frame grabber goes firstly to a memory which retains each single frame image in turn and then it goes to a signal processor which includes a comparator for the analysis of differences between different frames and the pixels contained within those frames.

In this respect the comparator firstly compares the image with previous images and by subtraction obtains a signal representative of the difference between successive frames. The system also includes an adjustable threshold

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An embodiment of the invention will now be described by way of example with reference to the accompanying diagrammatic drawings in which:-

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In this respect the comparator firstly compares the image with previous images and by subtraction obtains a signal representative of the difference between successive frames. The system also includes an adjustable threshold

control level, for sensitivity setting and a means by which changes which are representative of signal noise can be eliminated.

The output of the comparator is then subjected to the main processing of the signal in accordance with the present invention. Essentially the signal processor is looking to see whether there are changes in the individual pixels of a frame and in the differences between adjacent pixels which would have been caused by smoke particles. Thus if such dangerous changes have arisen an alarm is set off. In parallel with this, a monitor screen shows the region being monitored and can have an enhanced image superimposed on the raw TV camera image produced, so that the danger area is emphasised to an observer.

Now the signal processor involves a number of separate analyses and these involve mathematical analysis by appropriate computer software in the signal process as part of the equipment.

The signal processing means has to include hardware and/or software to recognise the selected conditions of change so that the presence of a smoke condition can be

identified.

The analysis can be based on the following:

Notation and concepts

The system has two images to work with, where image is defined as an ordered set of pixels intensities.

First it is necessary to define the set of possible pixel intensity values

$Z = \langle 0,1,2,3,...,M \rangle$

where M is the maximum pixel value.

An image is defined as an ordered set of pixel values where a pixel value is defined as:

$i_j \in Z$

Therefore an image can be denoted as follows

$I = \langle i_0, i_1, i_2, i_3, i_4, ..., i_N \rangle$

Where N is the number of pixels in an image.

The system provides two images in order to evaluate the various changes. These images are

R the reference image

C the current image

Given that a change has been identified this change is used to define a sub-set of the images.

$$R_\Delta \subseteq R$$
$$C_\Delta \subseteq C$$

With these sub-sets defined, the following metrics are evaluated:

Convergence to a common mean

There is the reference image R and the current image C. The set of pixels which are deemed to have changed are denoted C_Δ and R_Δ.

Let m be the mean value of the changes in C *i.e.*

$$m = \frac{1}{\#C_\Delta} \sum C_\Delta$$

where

$\#S$ denotes the number of element in the ordered set S and $\sum S$ denotes the sum of all elements in the ordered set S.

Once the value m has been defined the number of pixels whose intensity is approaching m with respect their corresponding value in the reference image is evaluated. With the same images the number of pixels whose intensities are departing from this mean value is also calculated.

$$n_{towards} = \sum \{\mathrm{sign}(C_\Delta - R_\Delta) = \mathrm{sign}(C_\Delta - m)\}$$

$$n_{away} = \sum \{\mathrm{sign}(C_\Delta - R_\Delta) \neq \mathrm{sign}(C_\Delta - m)\}$$

where the function **sign** is defined as follows for scalar values, when applied to an ordered set it is

$$\mathrm{sign}(x) \rightarrow \begin{array}{l} x<0:-1 \\ x=0:0 \\ x>0:1 \end{array}$$

defined to return an ordered set of values.

These two values provide a metric of "convergence to the common mean value" and passed forward to the decision system.

Static Becomes Dynamic

For any area which is being investigated, the consistency of the changing area is evaluated over time in order to assess if that area is dynamic in terms of its overall appearance or static. Lighting changes alter the image but the overall appearance does not change. The correlation function is used to evaluate this similarity over time since it is invariant to both scale and gain changes. If an object obscures the background by moving into the area of interest then the appearance within the area of interest will change. If the correlation fluctuates sufficiently over time then the area is deemed to be dynamic. This measure of consistency is forwarded to the decision system.

Edge content

A change in edge information is defined as a change in the value of the edge measure. The edge measure is defined as the sum of the responses of a standard derivative filter kernel where changes have been detected by the previous stage. A standard filter which is

employed is the Sobel edge filter. This measure of edge content is forwarded to the decision system.

Characteristics of shape

Various shape characteristics are employed including density and aspect ratio.

- Density is defined as the average number of occupied neighbours for all members of the change set. A "four connectivity" scheme is adapted and consequently the average value of density lies in the range 0 to 4.

- The aspect ratio is the ratio of the height to the width of the changed region.

When the density, aspect ratio and pixel count (i.e. the number of pixels that have changed in an area) are taken together they describe some of the shape characteristics of the changed area. These values are forwarded to the decision system.

System Description

The smoke detection hardware accepts video input on up to six parallel video streams. The hardware consists of an industrial PC with a 200 MHz MMX Pentium processor and 32 MB of system RAM. The PC contains a frame-grabber

card, of type MP300. The smoke detection software is written in C++, compiled using the WATCOM C++ compiler. The features described below in this invention are encapsulated in around 50 source code files and a further 50 header files, comprising an estimated 40,000 lines of code in all.

Algorithm Overview

The smoke detection algorithm examines, in general terms, the following features of a digitised video stream to determine whether smoke has been detected:

Pixels (or groups of pixels) moving towards a mean value
Edge information edge definition - this may increase or decrease as smoke emerges (depending on what it was like before)
Whether the image overall is static or dynamic
Emerging new shapes in the image - comparison of characteristic shape with indicative smoke shapes

The system works out the differences between the current image and a reference image. Important parts of the analysis are as follows:

Where image pixels appear to have changed, the algorithms

work out whether the image pixels are approaching or deviating from some common mean value

Edges - sum of responses of a standard deviation filter where changes were previously detected (the Sobel edge filter)

Correlation function to determine similarity over time.

Shape: density of the "changed" region - four nearest neighbours possible; aspect ratio; total area

Zones

Zones are rectangular regions selected from the entire image by the user when the system is installed. These would typically be arranged to cover likely areas where smoke might be produced, and (more importantly) not cover problem areas of the scene. Each zone is processed entirely separately, and the outputs from each zone may be combined to generate alarms as required. Pixels in the zone may additionally be eliminated so that they are not included in the calculations - for example, the filament of a light bulb, or a shiny metal object that glints in the sunlight. Again, these are selected by the user when the system is commissioned. At any one time there are two primary sets of image data for the zone - the current image and the reference image. The pixels in these images are denoted by x and x_r respectively, in

the discussions below.

Within each zone, a set of *n* parameters are calculated. These parameters are formed into an *n*-dimensional "vector" , defining a "feature" space.

Image data (planes) stored in the program

The following key image plane sets are stored by the software for each zone:

current image data

reference reference image data

change raw changed pixels

environment edge-sensitive detector values from reference image data

filter the combined "mask"

previous previous value of "filter"

eliminate mask of pixels eliminated manually

Basic operation

Frames are acquired from the frame grabber card on a regular basis. After any adjustments to normalise the brightness and contrast, the system compares the most recently acquired frame (current) with the reference frame. If pixels differ by more than an adjustable

threshold (camera noise may be taken into account too), then the pixel is deemed to have changed.

The reference image is acquired periodically, when the system has detected no changes in the scene, and when the system determines that the current scene is no longer similar enough to the reference image. This reference image is analysed to generate an "environment mask", using the EDGE algorithm below. This essentially indicates where there is edge detail in the zone.

A pixel-by-pixel "filter" mask, used in the calculations detailed below, is constructed by combining the changed pixels with the environment mask. The changed pixel mask is only copied to the final filetr mask at points where the magnitude of the difference between the current and the reference pixel exceeds the edge detail pixel value. Pixels selected manually as being problematic are also eliminated from this mask at this stage.

Low-level image processing operations

A large set of different image processing operations are carried out on the zone image data. Some of these operations use only the unmasked pixels, others operate on the entire set of pixels. These parameters are the

raw data fed into the final smoke detection algorithms. They are all relatively straightforward image processing primitives, but the definitions used in the algorithm are reproduced below for completeness.

MEAN

This is the simple mean value of the *N* pixel values, *x*, in the zone.

$$MEAN = \langle x \rangle = \frac{\sum x}{N}$$

TOWARDS_COMMON_MEAN

This parameter counts the number of unmasked pixels in the image that deviate from the mean with the same sign as they do in the reference image.

$$TOWARDS = \sum \left[sign(x - x_r) == sign(\langle x \rangle - x_r) \right]$$

FROM_COMMON_MEAN

This parameter counts the number of unmasked pixels in the image that deviate from the mean with the opposite sign from the way they do in the reference image.

$$FROM = \sum \left[sign(x - x_r) = sign(\langle x \rangle - x_r) \right]$$

COFGX

The mean x-co-ordinate of the unmasked pixels in the zone (this will change as areas in the zone are masked out)

COFGY

The mean y-co-ordinate of the unmasked pixels in the zone (this will change as areas in the zone are masked out)

SIZE

The total number of pixels in the zone, including the masked pixels

COUNT

The total number of unmasked pixels in the zone (i.e. excluding the masked pixels)

EDGE

The edge content algorithm looks at, for each unmasked pixel in the current image, the four adjacent pixels (up/down/left/right). It sums the sum of the magnitude of the differences between the left and right, and between the up and down pixels, for pixels where this exceeds a threshold value set by the user.

$$EDGE = \sum\left[\left\{\left|x_{up} - x_{down}\right| + \left|x_{left} - x_{right}\right|\right\}(if > threshold)\right]$$

EDGE_REF

The calculates the EDGE function, but based on the reference image pixels, instead of the current image pixels

CORRELATION

This is the correlation between the reference and the current image. This is calculated as:

$$CORR = \frac{\left(N * \sum x x_r - \sum x \sum x_r\right)}{\sqrt{\left(N * \sum x^2 - \left(\sum x\right)^2\right) \times \left(N * \sum x_r^2 - \left(\sum x_r\right)^2\right)}}$$

The correlation function is used as an overall "gate" to the detection process. If this correlation is greater than a preset SIMILARITY, then no further processing is carried out on the zone. This corresponds to the case where the image is essentially the same as the reference image.

CORRELATION_MASKED

The masked correlation calculates the same function as the correlation function above, considering only those pixels that are not masked.

VARIANCE

This is the standard variance of the pixel value, x, including all the pixels, calculated as

$$VAR = \left\langle x^2 \right\rangle - \left\langle x \right\rangle^2 = \frac{\sum x^2}{N} - \left(\frac{\sum x}{N}\right)^2$$

VARIANCE_REF

This is the standard variance of the reference pixel values, x_r, including all the pixels, calculated as

$$VAR = \left\langle x_r^2 \right\rangle - \left\langle x_r \right\rangle^2 = \frac{\sum x_r^2}{N} - \left(\frac{\sum x_r}{N}\right)^2$$

SKEW, KURTOSIS and FIFTH

These parameters look at the distribution of all the pixel values in the current image. As an example, the pixel values might have a Gaussian distribution about the mean pixel value, or the distribution might be asymmetric or otherwise non-Gaussian. Parameters such as skew, kurtosis and fifth are well known parameters used in statistics to analyse the non-Gaussian nature of distributions. They are calculated as follows:

Denoting $\sigma = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}$

$$SKEW = \frac{1}{N}\sum\left[\frac{x-\langle x \rangle}{\sigma}\right]^3$$

$$KURTOSIS = \frac{1}{N}\sum\left[\frac{x-\langle x \rangle}{\sigma}\right]^4$$

$$FIFTH = \frac{1}{N}\sum\left[\frac{x-\langle x \rangle}{\sigma}\right]^5$$

SKEW_REF, KURTOSIS_REF and FIFTH_REF

These look at the distribution, as above, in the reference image instead of the current image.

COMPACTNESS

This function looks at the four nearest pixels to each unmasked pixel, and calculates the mean number of these that are unmasked.

OPACITY

Opacity is calculated, for the unmasked pixels only, as

$$OPACITY = \frac{1}{N}\sum\left[\frac{x - x_r}{\langle x\rangle - x_r}\right]$$

RUNNING_CORRELATION_MEAN

This is the standard deviation of the CORRELATION as defined above. This is a running mean, as it is simply calculated from a set of total running sums.

RUNNING_MEAN_MEAN

This is the mean value of the masked correlation - as a running value.

EDGE_EVIDENCE

This is based on a mask of particular edges in the image. This mask is shrunk by one or two pixels all round. The unmasked pixels in the current and reference images are examined using the EDGE algorithm above. The routine then calculates the mean ratio of the pixels in the EDGE'd current image and those in the EDGE'd reference image, within the unmasked region, provided that the reference image contained a non-zero value.

PERCENTAGE_CHANGE

This is a measure of the percentage change in the number of masked pixels between the previous "filter" mask and the present one. These are Boolean masks, and the percentage change is calculated simply on the basis of the numbers of pixels that are non-zero (TRUE) in just one of the two images, normalised by the number that are non-zero in either or both.

The filter masks are "eroded" before this calculation, using an algorithm that only allows TRUE pixels to remain if all of its original four neighbours were also TRUE. This is a form of filtering to reduce the noise.

Rule-based Analysis

Rule-based analysis is used initially to determine whether a change in the image has occurred, and whether this change is significant. If it is, then further analysis is carried out to see if the change is considered to be associated with smoke, or whether it is associated with, say, a person walking across the scene.

The rule-based analysis uses a scoring system, where points are allocated for each rule which is met. If the points total exceeds a (variable) criteria (typically 90% of the maximum score), the analysis moves to the next level.

The analysis is carried out on a region, which is a subset of the area of the zone, defined by the edges of the unmasked pixels.

Check for no correlation

If the running correlation for this zone is very small (RUNNING_CORRELATION_MEAN<0.1), this means that the reference image and the current image are no longer similar (e.g. because the camera moved). If the image is not changing (PERCENTAGE_CHANGE<0.3), then it is time to update the zone's reference image, and abandon the current check for smoke.

Correlation less than threshold

If the correlation is less than the user-defined threshold, two points are scored, otherwise the check is abandoned.

Towards or from common mean

If the pixel values are tending towards the common mean, then this could indicate the presence of smoke (the whole image is becoming uniform grey). The algorithm looks at the ratio of the towards to from terms, and if this exceeds a user-adjustable ratio, three points are scored.

Edge-ness

The "edge-ness" of the region is the ratio of the EDGES to the COUNT of pixels in the image. This is calculated both for the current and the reference image. If the current image edge-ness is outside a preset band, three points are scored. An additional three points are scored if the edge-ness deviates from the reference edge-ness by more than a preset percentage - selectably either up or down.

Compactness

The COMPACTNESS (defined above) must lie within a preset band. If it deviates outside of this, three points are scored.

Edge evidence

The EDGE_EVIDENCE is decreased by the presence of smoke. If it falls below a preset threshold, three points are scored.

Scoring against criteria

The user may determine, when setting up the system, a subset of the available tests to carry out. The maximum score will be less, and the is take into account when determining whether the score has exceeded 90% of the maximum value. If it has, a Bayesian analysis is then carried out.

Bayesian Analysis

Bayesian analysis provides us with a well founded decision criteria which takes into account the co-variance of features and provides the ability to discriminate between different classes of event (nuisance and real alarms). An important fact to note when defining features for use with Bayesian analysis is that they should be invariant to external influences such as background and lighting. The algorithm can cope with some variation but in general the effects of external influences should be kept to a minimum.

Bayesian statistics are a useful tool in making decisions with multivariate systems such as this. The parameters (MEAN, TOWARDS_COMMON_MEAN etc) are combined together

into an *n*-dimensional vector. These vectors are used to "train" the system by building up a set of statistics. More specifically, the system stores data for nuisance and real alarms as separate classes. For an *n*-dimensional vector v the sums s and S are calculated for N different alarm events as follows, separately for nuisance and real alarms.

$$\mathbf{s} = \sum \mathbf{v}$$

$$\mathbf{S} = \sum \mathbf{v}\mathbf{v}^T$$

The Bayesian decision function takes a vector, v, from the current zone/region, and calculates a real decision value, d, as follows:

$$\mathbf{m} = \frac{\mathbf{s}}{N}$$

$$\mathbf{C} = \frac{\mathbf{S}}{N} - \mathbf{m}\mathbf{m}^T$$

$$d = 0.5 \times (\log|\mathbf{C}| + (\mathbf{v} - \mathbf{m})^T \mathbf{C}^{-1} \bullet (\mathbf{v} - \mathbf{m}))$$

d is calculated against the two reference classes - nuisance and real, giving d_n and d_r If d_r is greater than d_n, the Bayesian analysis signals an alarm condition.

If problems are experienced with overlapping responses in d_n and d_r , this might be solved by increasing the number of features and hence moving a to higher dimensional spaces (the probability of clouds overlapping by chance reduces as the dimensionality is increased).

Combination of Rules and Bayesian Analysis

It is crucial that the smoke detection system avoids false alarms. This is a key part of the system.

Thus an important feature of the invention is to combine a rule-based analysis with a atatistically based analysis, and particularly with one based on Bayesian analysis. The rule based analysis takes place first and if certain criteria are met then the Bayesian analysis is instigated.

Frequently, the Bayesian analysis and the rule-based analysis disagree. In this case, the confidence in the Bayesian analysis is used to determine whether the alarm is real or nuisance. The difference between real and nuisance is based on experience and the system builds up in accuracy over time.

If the Bayesian analysis showed an alarm, but the rule-based analysis did not, The difference between the values of d_r and d_n is used as a measure of the confidence in the alarm. If this exceeds the minimum confidence level, then an alarm is signalled, even though the rule-based analysis did not trigger and alarm

If the rule based analysis showed an alarm, and the Bayesian treatment did not, if the difference between d_n and d_r is more than the minimum confidence level, the alarm is cancelled.

If there is no alarm, but the correlation between the current and reference images is small, and the percentage change function is low, the reference image is updated.

This effectively adjusts for changes in, for example, lighting level.

CLAIMS

1. A smoke detection system comprising video camera monitoring means, video frame comparison means, signal processing means, and alarm generating means dependant on an output from the signal processing means; the signal processing means being arranged to analyse successive frames acquired by the video camera monitoring means and to compare the intensity and/or colour of individual pixels or group of pixels so as to consider the overall characteristics and inter-relationships of these pixels so as to detect the presence of smoke characterised in that the signal processing means analyses a plurality of different types of change in the said characteristics and inter-relationships.

2. A smoke detection system according to claim 1 in which the signal processing means is arranged to analyse the changes by a combination of a weighted rule based analysis and a statistically based analysis.

3. A smoke detection system according to claim 2 in which the statistically based analysis is a Bayesian analysis.

4. A smoke detection system according to claim 1 in which a change to be analysed is that the value of at least some of the pixels being analysed are identified as converging towards a mean value.

5. A smoke detection system according to claim 1 in which a change to be analysed is that pixels defining edge

information change from showing structured definition to showing a less structured level of information.

6.A smoke detection system according to claim 1 in which a change to be analysed is that dynamic parts of the overall image are identified as becoming static.

7. A smoke detection system according to Claim 1 in which a change to be analysed is that measured differences are identified as being distributed in small isolated groups.

8. A smoke detection system in which a change to be analysed is that the value of changed pixels as between a current image and a reference image indicates a reduction in visibility.

9.A smoke detection system according to claim 1 in which a change to be analysed is that new regions are identified as appearing which have characteristics of shape which resemble those of known shape characteristics of an emerging smoke or fire condition.

10. A smoke detection system according to claim 1 or 2 in which a plurality of the changes in accordance with at least any two of claims 4 to 9 is arranged to be analysed.

11.A smoke detection system according to claim 4 in which a number of frames are arranged to be analysed and the value of each pixel or pixel group is examined to see whether it is converging to a mean value.

12.A smoke detection system according to Claim 1 in which the signal processing means is arranged to analyse four different types of change, the first change being that the value of at least some of the pixels within the region are identified as converging towards a mean value, the second change being that pixels defining edge information change from showing structured definition to showing a less structured level of information, the third change being that the overall image ceases to be static and is identified as moving in an unpredictable manner and the fourth change being that new regions are identified as appearing which have shaped characteristics which resemble those of known shaped characteristics of an emerging smoke or fire condition.

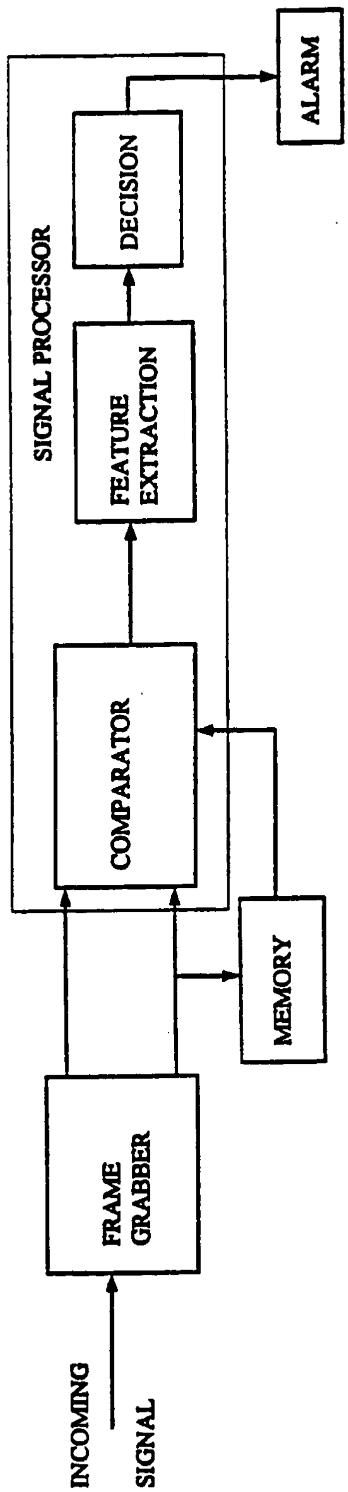
INCOMING
SIGNAL
FRAME
GRABBER
MEMORY
COMPARATOR
FEATURE
EXTRACTION
DECISION
SIGNAL PROCESSOR
ALARM

FIG.1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/03459

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G08B13/194

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G08B G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 237 308 A (TETSUYA NAKAMURA) 17 August 1993 (1993-08-17) column 6, line 15 -column 7, line 22; figure 1	1,2,8-10
X	WO 97 16926 A (DAVID SARNOFF RESEARCH CENTER) 9 May 1997 (1997-05-09) page 6, line 9 -page 8, line 23	1,2,8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 January 2000	04/02/2000

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte ,onal Application No
PCT/GB 99/03459

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5237308 A	17-08-1993	JP 2791229 B	27-08-1998
		JP 4263395 A	18-09-1992
		JP 2966551 B	25-10-1999
		JP 4263394 A	18-09-1992
WO 9716926 A	09-05-1997	NONE	